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A RAINFALL CLIMATOLOGY OF THE NWSFO MEMPHIS COUNTY WARNING AREA

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1. Introduction

Quantitative precipitation forecasting will be an important aspect of the modernized National Weather Service by providing more accurate predictions of how much rain is expected over specific river basins. Quantitative precipitation forecasts (QPFs) will be issued on a daily basis, and normally will include four six-hour forecasts of areally averaged rainfall over local river basins. River Forecast Centers (RFCs) will routinely include QPFs in their calculations of expected river stages, making QPFs a critical part of the prediction of floods and for the protection of life and property.

Some important aspects of the QPF forecasting program involve knowledge of the topography, river basins, normal rainfall patterns, rainfall frequency, and synoptic conditions associated with heavy rain events for the local area of responsibility. In the modernized NWS, the NEXRAD Weather Service Forecast Office (NWSFO) Memphis will issue QPFs for its present Hydrological Service Area (HSA) which includes the Missouri Bootheel, northeast Arkansas, west Tennessee and northern Mississippi (Fig. 1). This HSA is basically the same area as the Memphis County Warning Area (CWA) with only a few minor differences as shown in Fig. 1. The purpose of this paper is to provide a complete rainfall climatology for the Memphis CWA, addressing the important aspects of QPF forecasting which will serve as guidance for the quantitative precipitation forecaster.

2. Data

Much of the data used in this study was obtained from the National Climatic Data Center (NCDC) in Asheville, North Carolina. Monthly and annual rainfall "normals," 30-year averaged values from 1961-1990, from cooperative stations across the Memphis CWA were obtained from the *Climatography of the United States Series #81* paper published by NCDC. The locations of the cooperative stations included in the calculation of "normal" rainfall values are shown in Fig. 2.

Maximum rainfall frequency information for the Memphis CWA was obtained from a Weather Bureau publication entitled *Rainfall Frequency Atlas of the United States*. This technical paper was published in 1961 using 20 years of data and is the most current information available to the authors. It is assumed that this rainfall frequency information is still relatively accurate. Rainfall frequency graphs were compiled for Memphis using hourly precipitation data extracted from the Solar and Meteorological Surface Observation Network (SAMSON) CD-ROM distributed by NCDC. The manipulation of the raw hourly precipitation data for Memphis into six-hour frequency categories was accomplished with a computer program developed by Brain Walawender at NWSFO Topeka.

Hourly precipitation data for six stations across the Memphis CWA were obtained from NCDC on floppy discs. The stations were selected on the basis of having a relatively continuous 30-year hourly precipitation record from 1961 through 1990, and being spatially representative of the Memphis CWA. After analyzing the hourly precipitation data to determine heavy rain events, maps from the NOAA Daily Weather Map (Weekly Series) were used to evaluate the surface and 500 mb synoptic patterns on the selected heavy rain days.

3. Topography and River Basins

Most of the NWSFO Memphis CWA is located in the lower Mississippi River Valley with little variation in topography. Figure 3 shows the local topography analyzed using the elevations of the cooperative stations in Fig. 2. From this map one can get a general idea of the variations in local topography across the Memphis CWA.

The terrain of eastern Arkansas and the Missouri Bootheel is relatively flat except for Crowley's Ridge, which is an incline of around 150 to 200 ft above the surrounding topography. This ridge stretches north to south from central Clay County south to central Lee County and is generally 10 mi in width. Most of the vegetative cover across eastern Arkansas and the Missouri Bootheel is found on Crowley's Ridge, a mixture of deciduous and evergreen forests, with the rest of the area comprising mostly open farmland.

The topography of west Tennessee consists of a gentle upward slope away from the Mississippi River, ranging from 265 ft at Memphis to 580 ft at Paris. The vegetative cover across west Tennessee is thicker than that of eastern Arkansas and is comprised mainly of deciduous forests.

Northern Mississippi has the greatest variation in topography of the cooperative stations in the Memphis CWA, ranging from Ashland at 630 ft above sea level to Swan Lake at 145 ft above sea level. The highest point in the Memphis CWA is Woodall Mountain in Tishomingo County, Mississippi, which is 806 ft above sea level. This elevated topography separates the lower Mississippi River basin, into which most rivers across the Memphis CWA drain, from the Tombigbee River basin in northeast Mississippi, which flows south directly into the Gulf of Mexico. The vegetative cover across most of northern Mississippi comprises a mixture of deciduous and evergreen forests.

The locations of the river basins in the Memphis HSA are seen in Fig. 4. Table 1 provides a listing of the definitions of the river basins. These river basins are the watersheds of the river forecast points in the Memphis HSA. This means that any rain that falls, for example, in the MEMT1 river basin will cause a direct rise in the MEMT1 gauge reading at Memphis. QPF forecasters attempt to predict the average areal precipitation for each of these river basins in order to assist the RFCs in their prediction of river conditions for each individual gauge.

4. Normal Rainfall

An important tool for QPF forecasters is knowledge of the normal monthly rainfall of the local area and its spatial distribution. Normal rainfall for a specific station is determined from averaging the past 30 years of data every ten years, i.e., 1941-1970, 1951-1980, and 1961-1990. The "normal" rainfall for the Memphis CWA as a whole was determined by averaging the known normal (1961-1990) monthly rainfall amounts from seven stations which adequately represent the CWA (Fig. 5). The stations used to represent the Memphis CWA are Jonesboro, Arkansas; Paris, Jackson, and Memphis, Tennessee; Clarksdale, Tupelo, and Columbus, Mississippi.

Figure 5 shows that the wettest month of the year across the Memphis CWA is December, with around 5.5 inches, while October is the driest with around 3.2 inches. The five-month period of June through October (summer through most of fall) can be considered the dry season, as only a third of the total annual rain occurs during this period. The seven-month period of November through May (late fall through spring) can be considered the wet season, when two-thirds of the annual rainfall occurs across the CWA.

Normal rainfall across the Memphis CWA increases from 48 inches across sections of northeast Arkansas and the Missouri Bootheel to over 58 inches in northeast Mississippi. This general pattern of rainfall could be the result of developing low pressure systems over the Gulf of Mexico creating an increase in rainfall across the CWA as they move northeast, on average. A contributing factor may be that most cold fronts are oriented southwest to northeast as they cross the Memphis CWA. As these fronts move from west to east, on average, the available moisture, (from the Gulf of Mexico to the south), would have more time to be pulled northward, thus resulting in heavier rain farther north as one traveled east. Although variations in topography are minimal across the Memphis CWA, there seems to be a slight increase from southwest to northeast which might have a slight effect on this rainfall distribution.

Monthly rainfall maps were grouped together according to the seasons of the year, defined in this study according to the standard meteorological classification: December-February (winter), March-May (spring), June-August (summer), and September-November (fall). In the winter (Fig. 7), rainfall patterns reveal a definite northwest to southeast pattern with large differences in rainfall amounts. This can be attributed to the fact that synoptic scale fronts (predominately oriented southwest to northeast) and developing lows in the Gulf of Mexico are the dominant features during these months. Synoptic fronts create widespread rainfall patterns without significant localized effects.

During the first two spring months (Fig. 8), the northwest to southeast rainfall pattern is still seen, but it is not as definite and does not have as large a difference in rainfall amounts as the winter months. In May, rainfall amounts are similar across the entire CWA, which might be attributed to an increased likelihood of stalled or slow moving cold fronts which generally become weaker during the late spring in the Memphis CWA.

The summer rainfall patterns (Fig. 9) reveal that topography might have somewhat of a role in the formation of afternoon thunderstorms. While rainfall amounts are generally evenly divided across the CWA, there appears to be a minimum over eastern Arkansas, with the higher terrain over west Tennessee and northern Mississippi apparently enhancing amounts somewhat in these areas. Also, the prevailing south to southwesterly wind during the summer, bringing moisture from the Gulf of Mexico, would likely create higher rainfall amounts across the southeastern sections of the CWA.

Rainfall amounts during the fall (Fig. 10) are fairly evenly distributed, especially during September and October. This is likely the result of a lack of afternoon convection and strong fronts during these months which would usually cause significant variations in rainfall distribution in other months. The northwest to southeast rainfall gradient begins to develop in November as stronger cold fronts reach the area, but the differences in amounts are not as great as during the winter.

5. Rainfall Frequency

A frequent question about rainfall in any area is, "What is considered a heavy rain and how often does it occur?" Using charts from the *Rainfall Frequency Atlas of the U.S.*, the maximum amount of rain in 3-, 6-, 12-, and 24-hour time periods across the Memphis CWA once every 100 years was determined (Fig. 11). A compilation of maximum rainfall amounts, using the other return periods of 1, 2, 5, 10, 25, and 50 years from the *Rainfall Atlas of the U.S.*, was produced (Table 2) in order to show the maximum amounts of rainfall expected in 3-, 6-, 12-, and 24-hour periods.

Graphs showing the frequency of rainfall for different intensity categories were developed using the Memphis hourly precipitation data. On an annual basis (Fig. 12), a maximum in light rainfall amounts (0.01-0.49 inch) tends to occur between noon and 6 p.m. local time, while a maximum in heavy rainfall amounts (>0.49 inch) tends to occur between 6 p.m. and midnight. While the temporal differences in the distribution of rainfall amounts are subtle, the slight maxima in both light and heavy rainfall categories during the afternoon and evening hours are most likely the result of the diurnal increase in convection as a result of solar heating. It is also interesting to note that in all seasons, a noticeable drop in the rainfall frequency in the 0.05-0.09 inch category is observed. This result eludes any explanation from the authors.

During the winter months (Fig. 13), rainfall is fairly evenly distributed between the different periods, with a nocturnal bias noted between midnight and 6 a.m. for most rainfall amounts. In the spring (Fig. 14), light rainfall (<0.25 inch) occurs mainly during the 6 a.m. to noon period, while the majority of the heavier rainfall (>0.24 inch) occurs during the 6 p.m. to 6 a.m. time period, again showing a nocturnal bias. The summer months (Fig. 15) have most rainfall occurring between noon and 6 p.m., with the 6 p.m. to midnight hours nearly as active. During fall (Fig. 16), most rainfall amounts are fairly evenly distributed with an afternoon maxima observed for most categories between noon and 6 p.m.

There seems to be a slight increase in rainfall occurrence for amounts greater than an inch between the hours of 6 p.m. and 6 a.m. during the winter and spring. While during the summer and fall, there is an afternoon and evening maximum between the hours of noon and midnight. The observed maximum during the summer and fall months is most likely the result of afternoon and early evening thunderstorms. The nocturnal bias during the winter and spring months is likely the result of (1) the average wind speeds in the boundary layer being greater at night, leading to greater advection of low level moisture; (2) greater instability in cloudy locations due to cooling aloft and little temperature change below the clouds; and (3) afternoon convection leading to mesoscale boundaries and successive cells over the same area (train echo effect) several hours later, often after sunset. (Hoxit, *et al.* 1978)

6. Meteorological Conditions of Past Heavy Rain Events

An important tool for local forecasters in the prediction of heavy rain is the recognition of the surface and upper air patterns which lead to heavy rains across the area of concern. Thirty years of hourly precipitation data were analyzed at six selected stations which were chosen to spatially represent the Memphis CWA (Fig. 17). A heavy rain event is defined for the Memphis CWA using two criteria: (1) one that produces, at two or more stations, 3 or more inches of rain in 12 hours or less, which is roughly the maximum amount of rain expected in a 12-hour period every two years (Weather Bureau 1961) and (2) one that produces at least 6 inches in 12 hours or less at a single station, which is about the maximum amount of rain expected once every 100 years at a particular site in the Memphis CWA.

Selecting two or more stations with the criterion of 3 or more inches in 12 hours or less was done to ensure that the heavy rain was truly the result of a large scale pattern and not just an isolated event such as a heavy thunderstorm. Also, by using at least two stations, any flaws or incorrect data should be filtered out. After selecting the dates from which at least 3 inches of rain fell in 12 hours or less at one station, the dates were cross checked with the other five stations to see if heavy rain fell at another station within the same general time frame. Heavy rain at two separate stations was considered to be from the same event if the starting time of rainfall at one station was within 12 hours of the ending time of rainfall at the other station.

After the dates of heavy rain events were determined, copies of the Daily Weather Map charts for each of the selected dates were obtained and analyzed. The result is shown in Table 3. Events were classified according to Maddox, *et al.* (1979) reflecting four different conditions that produce flash flooding rains, which will be considered in this study to categorize heavy rain events. The "western" category deals with conditions that are exclusively found in the western U.S. and thus will not be considered for this study. Maddox, *et al.* (1979) excluded those events that were tropical in origin, but tropical events will be identified in this study because of the obvious influence of the Gulf of Mexico.

"Synoptic" events are those which are the result of an intense synoptic scale cyclone or frontal system. Synoptic events normally develop in association with a quasi-stationary or slow moving front, usually oriented from southwest to northeast, with an east to northeast moving trough at 500 mb and with heavy rains occurring in the warm sector ahead of the front. "Frontal" events were defined as those developing in association with a stationary or very slow moving front, usually oriented from west to east, with heavy rains found near the 500 mb ridge, and with heavy rains usually occurring on the cool side of the surface front.

"Mesohigh" events occur in association with quasi-stationary thunderstorm outflow boundaries which are generated by previous convective activity. The heaviest rains usually occurred near the 500 mb large scale ridge position and on the cool side of the surface boundary, usually to the south or southwest of the mesohigh center. With the criterion of two or more stations to define most heavy rain events in this study, some mesohigh events may have been filtered out. Also, because the Daily Weather Map publication shows only large scale features with limited mesoscale resolution, some mesohigh events may have been inadvertently overlooked and classified as synoptic events. However, most mesohigh events which produced widespread heavy rains, instead of the typical isolated heavy rains common during the summer, were examined. Because of their rarity, a study of these will be more useful to the QPF forecaster.

Of the 33 heavy rain events examined in this study, over half were classified as synoptic (18 total events). Seven occurred during spring, seven during fall, and four during winter. Only seven events were classified as frontal—three in the winter and four in the spring. Five events were classified as mesohigh—two in the summer, two in the fall, and one in the spring. Three events were classified as tropical—one in the summer (July) and two in the fall (September). All frontal events and the vast majority of synoptic events occurred during the wet season of November through May, while all but one of the mesohigh and tropical events occurred during the dry season of June through October. The final seasonal breakdown revealed that heavy rains are possible throughout the year, with 12 heavy rain events occurring during the spring, 11 during the fall, seven during the winter, and three during the summer. As for extremely heavy rainfall events with 6 inches or more, four occurred during the fall, three during the spring, two during the winter and one during the summer. Four of the latter were synoptic events, three were mesohigh events, two were frontal events, and one was a tropical event.

Surface dewpoint temperatures for each event were also evaluated using the highest 6 a.m. CST dewpoint temperature at Memphis compiled from each series of Daily Weather Maps which comprised a single event. While this method does not necessarily reveal the highest dewpoint temperature before the start of a heavy rain event, especially when there is significant moisture advection, it is the only feasible way to estimate dewpoint temperatures from the Daily Weather Maps, and it is assumed to be fairly representative in most cases. Using this method, it was discovered that over 90% of the heavy rains occurred with a dewpoint temperature between 50 and 75 F. The range of dewpoints during the winter and early spring (including March) was from 40 to 65 F, with over three-fourths occurring between 50 and 59 F. During the late spring (April and May), all events occurred with a dewpoint above 60 F, with half occurring with a dewpoint of 70 F or above. All events during the summer had dewpoints of 70 F or above. During the fall, dewpoints ranged from 55 to 75 F, with more than half of the events occurring with a dewpoint above 65 F.

Maddox, *et al.* (1979) also found that most flash floods occurred at night, particularly with frontal and mesohigh events. In this study, a heavy rain event was considered nocturnal if the starting time of rainfall occurred between sunset and sunrise (roughly 7 p.m. to 7 a.m. local time during the spring and fall, 5 p.m. to 7 a.m. during the winter, and 8 p.m. to 6 a.m. during the summer). With this criterion, around a third of the heavy rain events in this study were found to be exclusively nocturnal. Of the 13 total nocturnal events, seven were synoptic in nature, four were frontal, and two were mesohigh in nature.

7. Conclusions

The gradient of normal annual rainfall across the Memphis CWA is generally from the northwest to the southeast, ranging from 48 inches across sections of northeast Arkansas and the Missouri Bootheel to over 58 inches in northeast Mississippi. This general pattern is likely the result of developing low pressure systems over the Gulf of Mexico creating an increase in rainfall across the CWA as they move northeast, on average, and possibly the influence of cold fronts that are oriented southwest to northeast as they cross the Memphis CWA. As these fronts move from west to east, on average, the available moisture from the Gulf of Mexico would have more time to be pulled northward, thus resulting in a more northern extent of rain as one traveled east. Although variations in topography are minimal across the Memphis CWA, there is a rise of 200-300 ft from the southwest to the northeast which might have a slight effect on the annual rainfall distribution, especially with summer convection, as a slight maximum of rainfall is observed across west Tennessee and northern Mississippi during the summer months.

It was determined that the "wet season" for the Memphis CWA can be considered from November through May, with frontal and low pressure systems being the dominant heavy rain producing systems during these months. The "dry season" can be considered from June through October, with mesohigh and tropical systems being the dominant heavy rain producing events during these months. During the dry season, there is an afternoon maximum in frequency of rainfall which is most likely the result of thunderstorms caused by solar heating. The maximum in rainfall frequency during the wet season was found to be slightly greater at night which could be the result of destabilization effects from cloud top radiation and cooling at middle and high levels, the diurnal cycle in boundary layer wind speeds and the evolution of mesoscale pressure systems generated by convective activity (Hoxit, *et al.* 1978).

A heavy rain event can be defined for the Memphis CWA as one that produces rainfall of 3 inches or greater in a 12-hour period or less at two or more selected stations, or 6 inches or more in a 12-hour period or less at a single station. Although there is a minimum during the summer, heavy rain events are possible in all seasons throughout the year across the Memphis CWA. Most heavy rain events in this study were synoptic in nature, as defined by Maddox, *et al.* (1979), with roughly a third of all events being exclusively nocturnal, as defined in this study. One common feature for the vast majority of heavy rain events in the Memphis CWA was a southwest flow at 500 mb. Also, most heavy rain events during the year occurred with dewpoint temperatures above 60 F, with 50 F being the minimum in winter for most cases.

Forecasters who have been in the local area for some time likely are well aware of these findings; but forecasters new to the area, particularly those from other parts of the country, may not be as familiar with this information. It is important for these new forecasters to quickly become knowledgeable of the local rainfall climatology. With this knowledge they will be able to issue better QPFs, which in turn will make for better river forecasts which can be critical in times of major flooding.

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References

Hoxit, L.R., R.A. Maddox and C.F. Chappell, 1978: On the nocturnal maximum of flash floods in the Central and Eastern U.S. *Preprints, Conference on Weather Forecasting and Analysis and Aviation Meteorology*, Silver Spring, MD, Amer. Meteor. Soc., pp. 52-57.

Maddox, R. A., C. F. Chappell, and L. R. Hoxit, 1979: Synoptic and meso-α scale aspects of flash flood events. *Bull. Amer. Meteor. Soc.*, **60**, 115-123.

Table efinitions of River Basins across the Memphis HSA.

EAST ARKANSAS and MISSOURI BOOTHEEL

- HEEA4 - Helena (Mississippi River)
- LCRA4 - Lake City (St. Francis River)
- MSNA4 - Madison (St. Francis River)
- PLGA4 - Palestine (L'Anguille River)
- RIGA4 - Riverdale (Right Hand Chute Little River)
- SFRA4 - St. Francis (St. Francis River)

WEST TENNESSEE

- BOGT1 - Bogota (Obion River)
- BVRT1 - Bolivar (Hatchie River)
- DYET1 - Dyersburg (North Fork of the Forked Deer River)
- GERT1 - Germantown (Wolf River)
- HLST1 - Halls (South Fork of the Forked Deer River)
- JKNT1 - Jackson (South Fork of the Forked Deer River)
- MEMT1 - Memphis (Mississippi River)
- NOMT1 - Martin (North Fork of the Obion River)
- RLTT1 - Rialto (Hatchie River)
- 9ALT1 - Alamo (Middle Fork of the Forked Deer River)
- 9BRT1 - Brunswick (Loosahatchie River)
- 9KNT1 - Kenton (South Fork of the Obion River)
- 9KTT1 - Kenton (Rutherford Fork of the Obion River)
- 9OBT1 - Obion (Obion River)
- 9PHT1 - Pocahontas (Hatchie River)
- 9RVT1 - Rossville (Wolf River)

NORTHERN MISSISSIPPI

- ABDM6 - Aberdeen (Buttahatchie Creek)
- ABEM6 - Aberdeen Lock and Dam (Tombigbee River)
- AMYM6 - Amory (Tombigbee River)
- ARKM6 - Arkabutla Dam (Coldwater River)
- BGBM6 - Bigbee (Tombigbee River)
- BRCM6 - Bruce (Skuna River)
- BTGM6 - Batesville (Little Tallahatchie River)
- CBUM6 - Columbus Lock and Dam (Tombigbee River)
- CCTM6 - Calhoun City (Yalobusha River)
- CLUM6 - Columbus (Luxapallila Creek)
- ENDM6 - Enid Dam (Yocona River)
- ETAM6 - Etta (Little Tallahatchie River)
- FULM6 - Fulton (Tombigbee River)
- GRNM6 - Grenada Dam (Yalobusha River)
- LEGM6 - Lewisburg (Coldwater River)
- LMGM6 - Lambert (Tallahatchie River)
- MCNM6 - Macon (Noxubee Creek)
- OXDM6 - Oxford (Yocona River)
- SARM6 - Sarah (Coldwater River)
- SHHM6 - Senatobia (Hickahala River)
- SRDM6 - Sardis Dam (Tallahatchie River)
- SWNM6 - Swan Lake (Tallahatchie River)
- TBBM6 - Tibbee (Tibbee Creek)
- TPOM6 - Tupelo (Town Creek)
- TPGM6 - Potts Camp (Tippah River)
- 9PRM6 - Lewisburg (Pigeon Roost River)

Table 2. Maximum Expected Rainfall for the Memphis CWA (in inches).

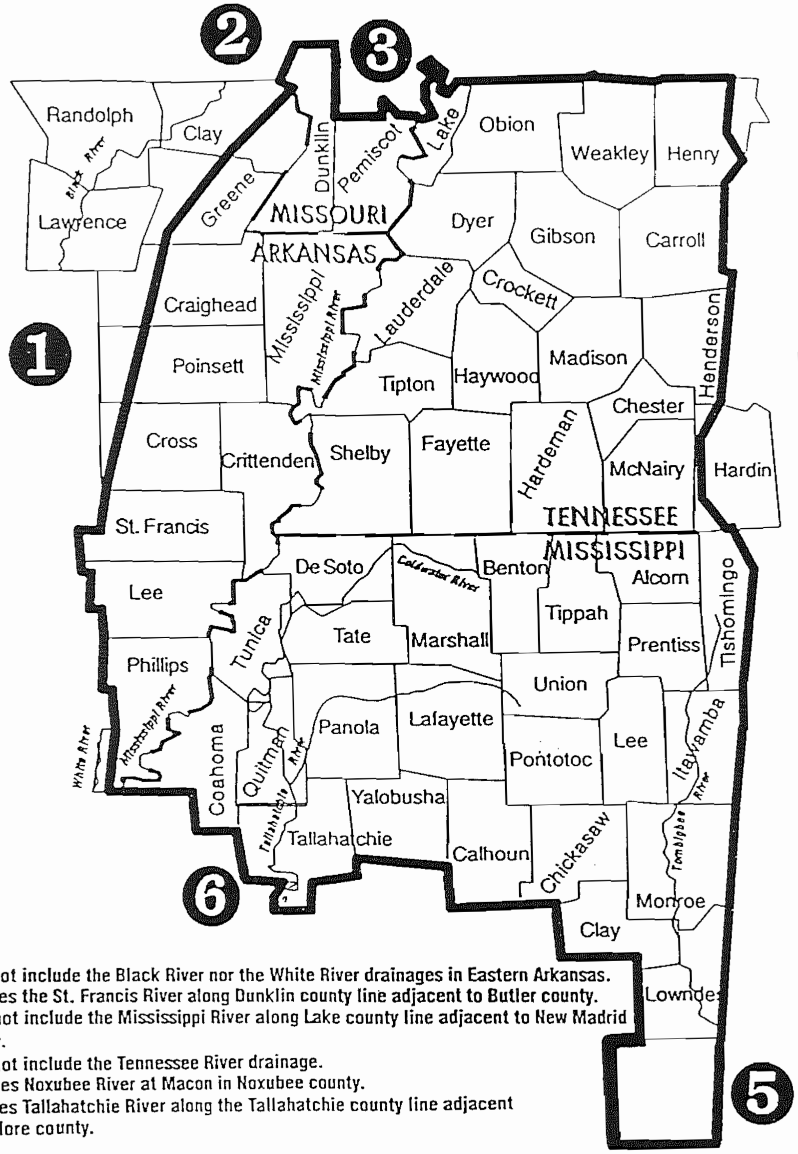
	RETURN PERIOD						
RAIN DURATION	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
3 Hour	1.80-2.20	2.25-2.50	2.75-3.25	3.00-3.50	3.50-4.00	4.00-4.50	4.25-5.00
6 Hour	2.25-2.50	2.75-3.00	3.30-3.75	3.75-4.25	4.25-5.00	4.75-5.50	5.00-6.00
12 Hour	2.75-3.00	3.25-3.75	3.75-4.50	4.30-5.25	4.75-6.00	5.50-6.50	6.00-7.50
24 Hour	3.10-3.50	3.50-4.25	4.50-5.30	5.00-6.00	5.75-7.00	6.50-7.75	7.00-8.50

Source: 'Rainfall Frequency Atlas of the United States', Technical Paper #40, Weather Bureau, May 1961.

Table 3. Dates and types of past 'heavy rain' events across Memphis CWA.

Dates of Events	Surface Feature	500 mb Pattern	Classification
September 10-11, 1965	Strong low pressure w/cold front (W-E) approaching from NW	Closed low w/south flow (50 kts)	Tropical (Betsy)
February 9-10, 1966	Slow moving cold front (N-S) with squall line	Strong trough with strong southwest flow (80 kts)	Synoptic
May 12-13, 1967 (6.09" at Greenfield) (>3.0" at Corning)	Stationary front (W-E) w/squall line north of frontal boundary	Strong west zonal flow (75 kts) near weak ridge	Frontal
November 18-19, 1969	Strong cold front (N-S)	Strong trough w/strong southwest flow (100 kts)	Synoptic
October 11-12, 1970	Quasi-stationary front (N-S)	Closed low w/weak southwest flow (30 kts)	Synoptic
February 21, 1971	Strong warm front (W-E) moving north	Strong closed low with strong southwest flow (100 kts)	Frontal
September 25, 1972 (6.23" at Corning) (isolated event)	Thunderstorm outflow boundary	Weak southwest flow (30 kts) along weak anticyclone to the east	Mesohigh
March 14-16, 1973	Slow moving cold front (N-S)	Deepening trough with strong southwest flow (80 kts)	Synoptic
November 26-27, 1973	Developing low along slow moving cold front (N-S)	Strong trough w/strong southwest flow (70 kts)	Synoptic
May 14-15, 1974	Stationary front (W-E) w/squall line to the south	Westerly zonal flow (30-40 kts)	Mesohigh
May 31 - June 1, 1974	Developing low along slow moving cold front (N-S)	Weak trough w/weak southwest flow (30 kts)	Synoptic
March 12-13, 1975	Quasi-stationary front (W-E) w/developing low	Weak ridging w/strong southwest flow (70 kts)	Frontal
March 27-28, 1975 (7.22" at Corning) (>3.0" at Greenfield)	Warm front moving north (W-E) becoming quasi-stationary	Closed low with southwest flow (50 kts)	Frontal
March 3, 1977	Slow moving cold front (N-S)	Closed low w/strong southwest flow (70-80 kts)	Synoptic
May 6-7, 1978	Warm front (W-E) moving north	Closed low with southwest flow (40kts)	Frontal
December 2-3, 1978	Strong cold front (N-S)	Strong trough w/strong southwest flow (60-70 kts)	Synoptic
April 11-12, 1979	Cold front (N-S) assoc. w/strong low	Closed low w/strong southwest flow (50-60 kts)	Synoptic

Dates of Events	Surface Feature	500 mb Pattern	Classification
March 16-17, 1980	Strong cold front (N-S) with squall line	Strong trough w/strong southwest flow (70 kts)	Synoptic
June 23-24, 1980 (7.1" at Clarksdale) (>3.0" at Memphis)	Quasi-stationary front (W-E)	Closed low with weak north flow (20-30 kts)	Mesohigh
July 21-22, 1980	Slow moving weak cold front (N-S)	Weak trough w/weak west flow (20 kts)	Mesohigh
October 17-18, 1981	Quasi-stationary front (W-E) w/strong cold front (N-S)	Deepening trough w/strong west flow (60-70 kts)	Synoptic
September 12-13, 1982 (11.9" at Greenfield) (isolated event)	Low pressure system	Weak southwest flow (20 kts)	Tropical (Chris)
December 3-4, 1982	Slow moving cold front (N-S)	Strong closed low with south flow (50 kts)	Synoptic
April 4-5, 1983	Slow moving cold front (N-S)	Closed low with southwest flow (50 kts)	Synoptic
May 18-19, 1983 (6.4" at Booneville) (>3.0" at Aberdeen)	Warm front (W-E) moving north w/cold front (N-S) later	Closed low w/strong southwest flow (50-60 kts)	Synoptic
December 2-3, 1983	Developing low along stationary front (W-E)	Weak trough approaching from west w/weak ridging and southwest flow (50 kts)	Frontal
October 6, 1984 (6.0" at Clarksdale) (>3.0" at Greenfield)	Thunderstorm outflow boundaries	Weak trough with weak southwest flow (30 kts)	Mesohigh
October 22, 1984 (7.4" at Aberdeen) (isolated event)	Slow moving cold front (N-S)	Strong trough w/strong southwest flow (60 kts)	Synoptic
November 7-8, 1986	Cold front (N-S) with squall line	Strong trough w/strong southwest flow (70 kts)	Synoptic
November 16, 1987	Cold front (N-S) with squall line	Strong trough w/strong south flow (70 kts)	Synoptic
December 24-25, 1987 (6.42" at Jackson) (isolated event)	Strong warm front (W-E) ahead of slow moving cold front	Closed low with southwest flow (50 kts)	Frontal
July 1-2, 1989	Slow moving low pressure system	Closed low with weak west flow (20 kts)	Tropical (Allison)
February 3, 1990 (6.1" at Clarksdale) (>3.0" at Booneville)	Quasi-stationary front (N-S) ahead of strong cold front (N-S)	Strong trough w/strong southwest flow (80 kts)	Synoptic



1. Does not include the Black River nor the White River drainages in Eastern Arkansas.
2. Includes the St. Francis River along Dunklin county line adjacent to Butler county.
3. Does not include the Mississippi River along Lake county line adjacent to New Madrid county.
4. Does not include the Tennessee River drainage.
5. Includes Noxubee River at Macon in Noxubee county.
6. Includes Tallahatchie River along the Tallahatchie county line adjacent to Leflore county.

Figure 1. Counties of the NWSFO Memphis County Warning Area (CWA) with bold line outlining the Hydrological Service Area (HSA).

Figure 2. Cooperative stations reporting precipitation in the Memphis CWA.

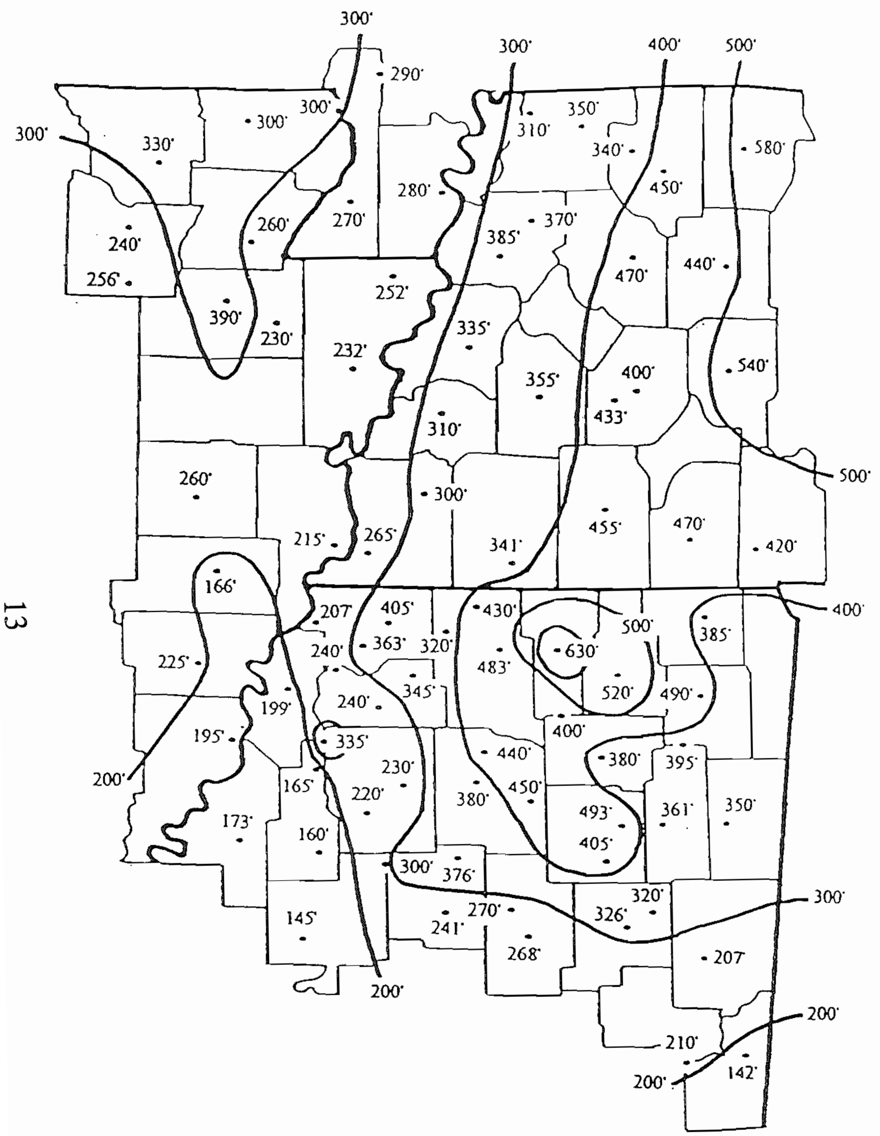


Figure 3. Elevations of the cooperative stations across the Memphis CWA.

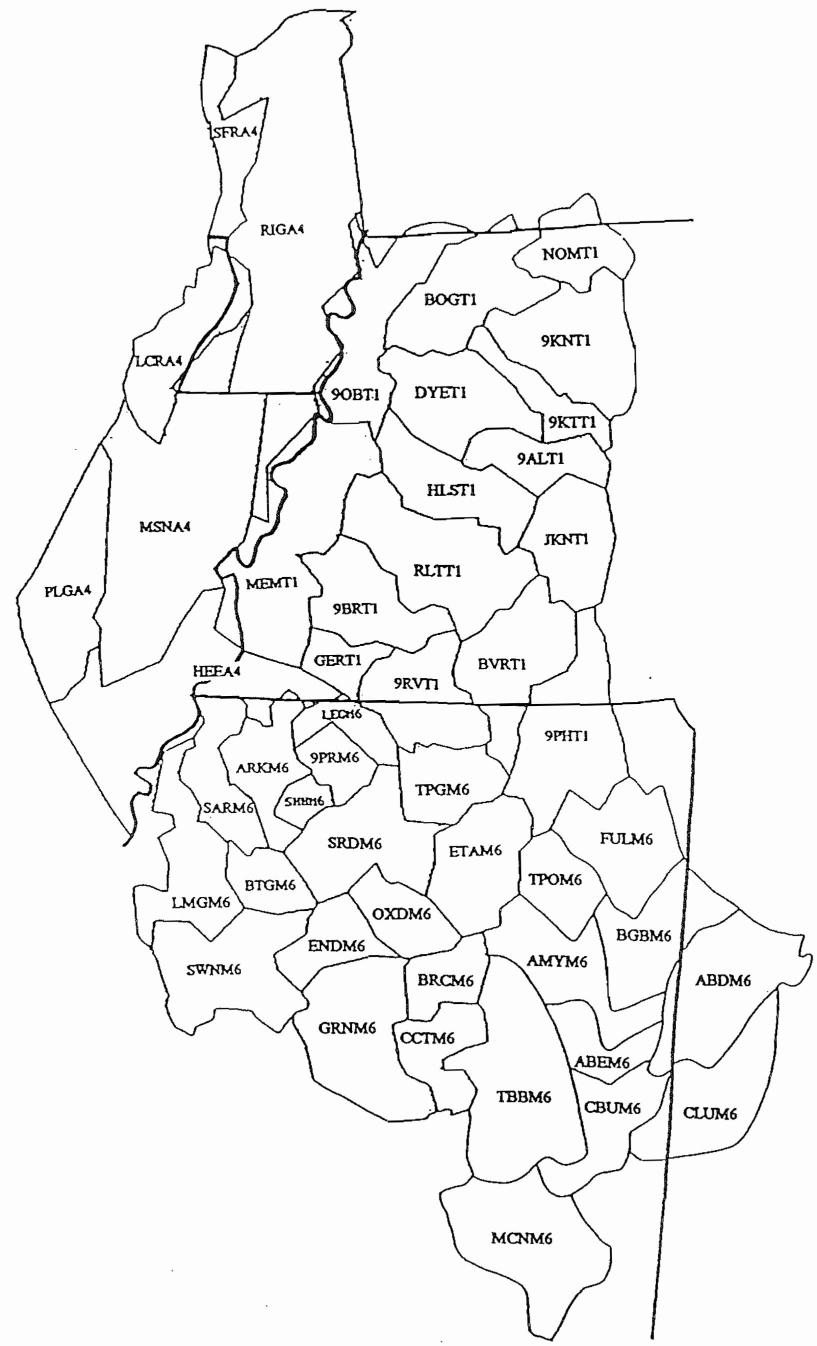


Figure 4. River basins across the Memphis HSA (bold lines are state boundaries); refer to Table 1 on next page for definitions of river basins.

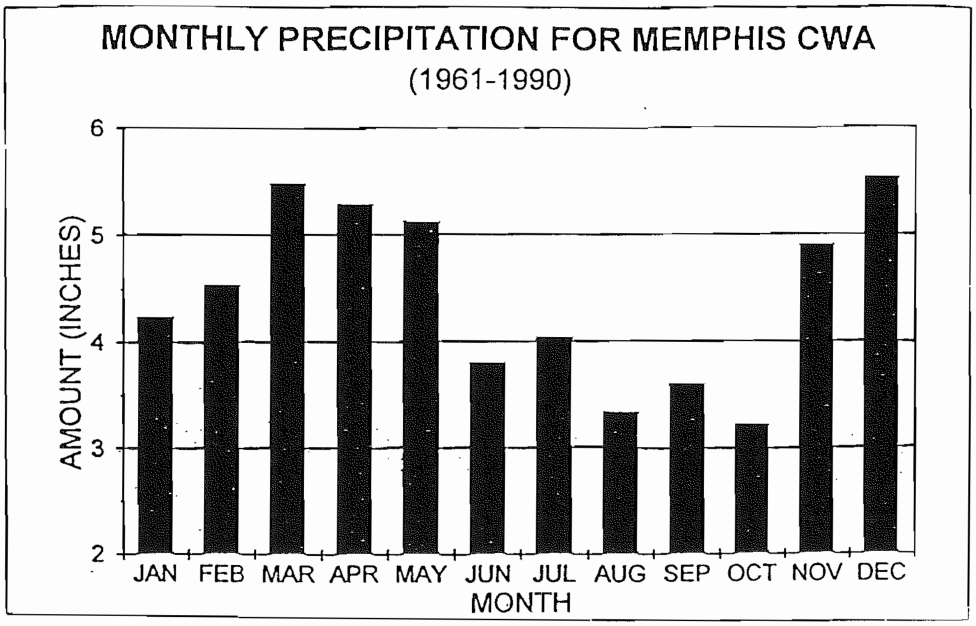


Figure 5. Normal monthly precipitation for the Memphis CWA.

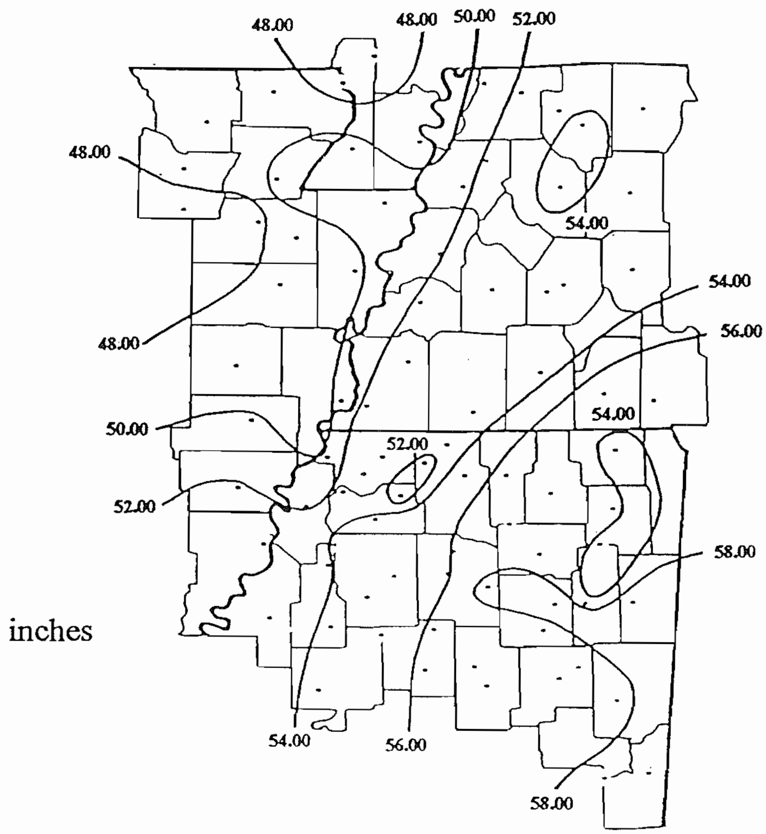
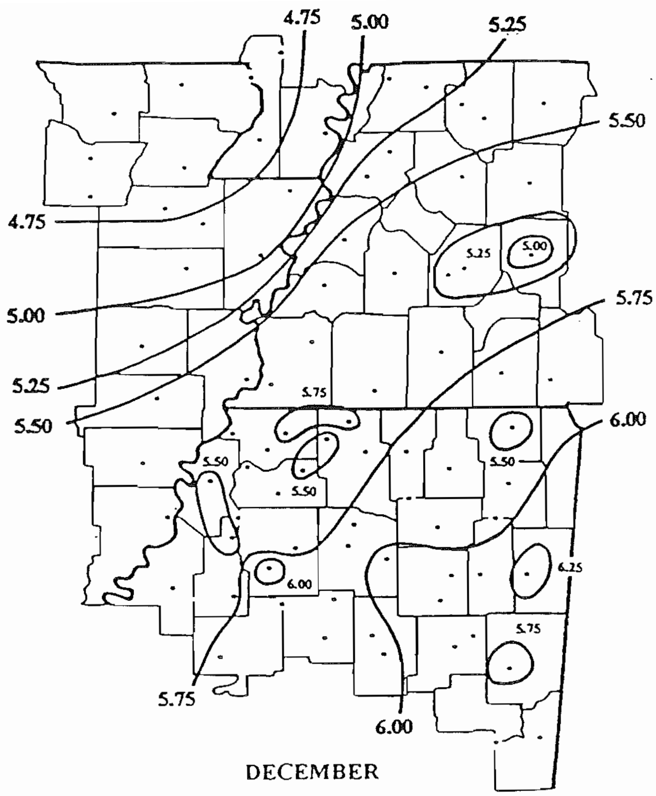


Figure 6. Distribution of the normal annual precipitation across the Memphis CWA.



(in inches)

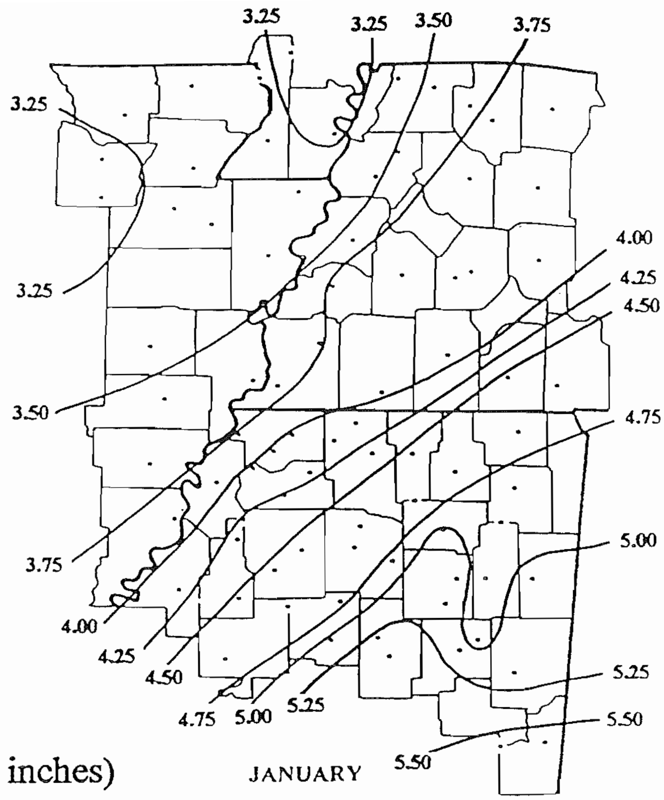
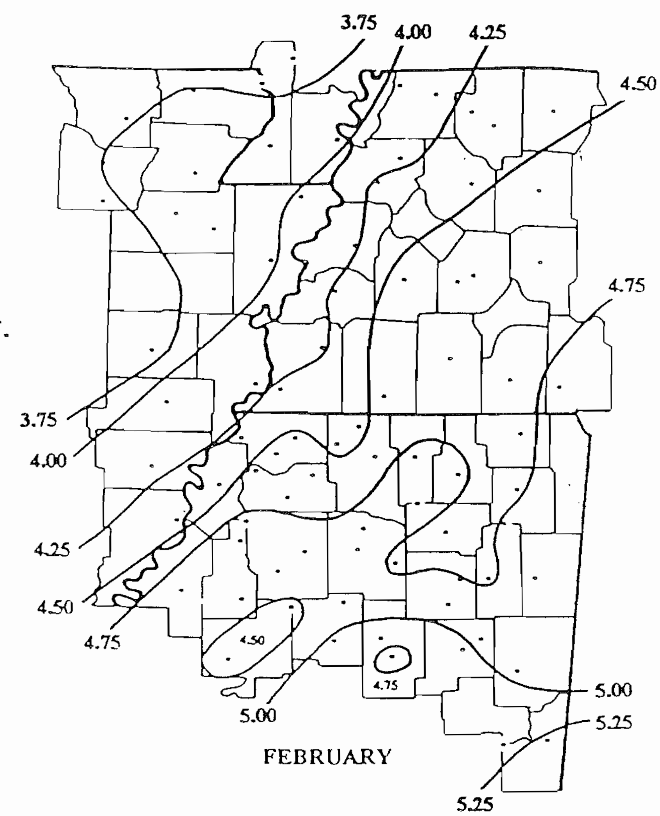
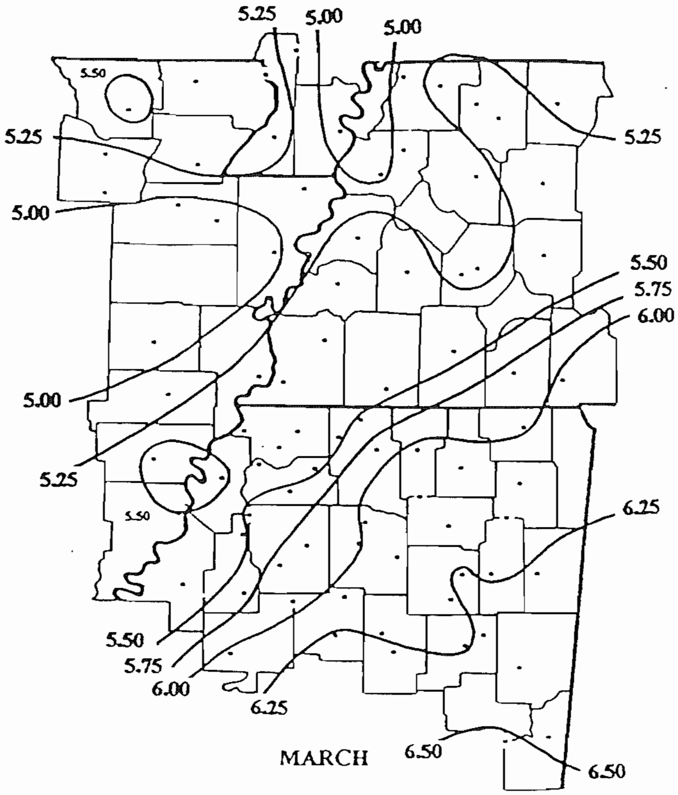
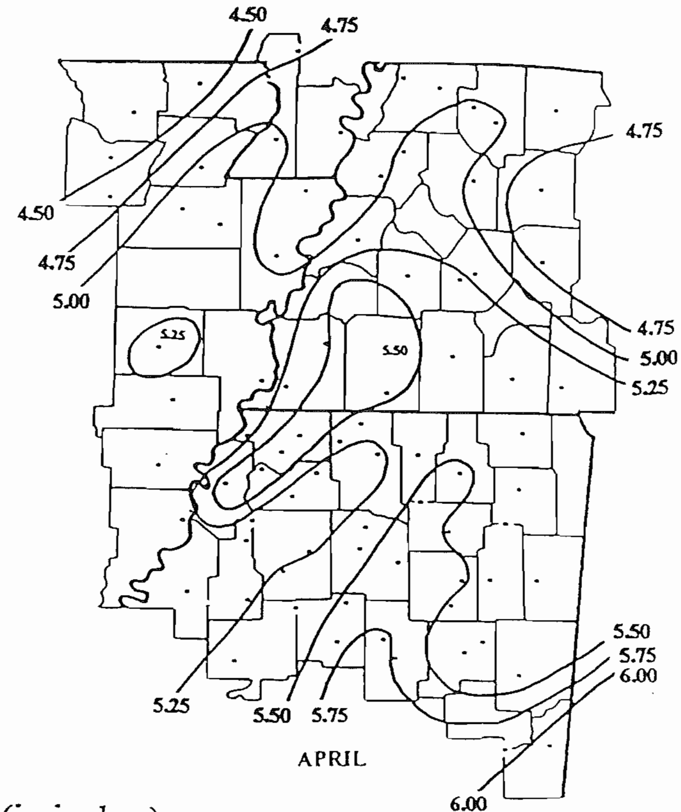


Figure 7. Distribution of normal precipitation across Memphis CWA during winter.







(in inches)

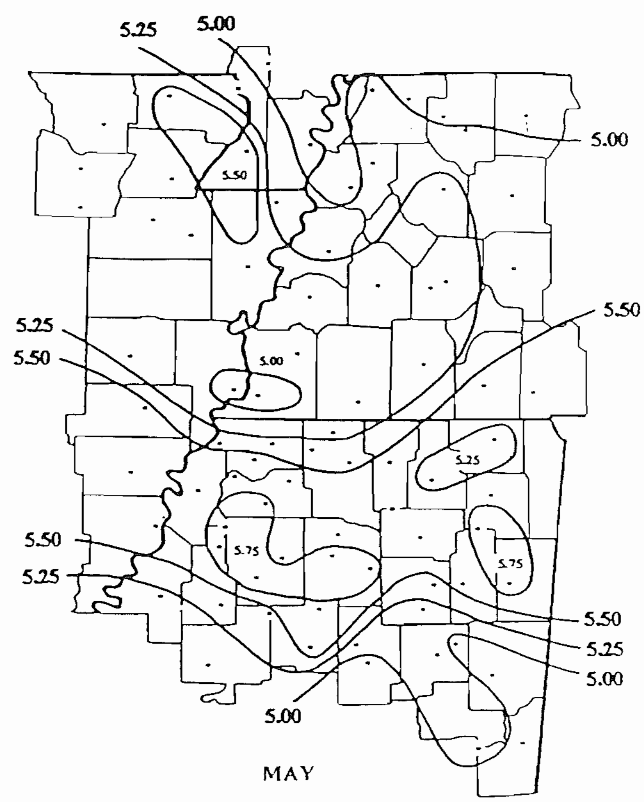
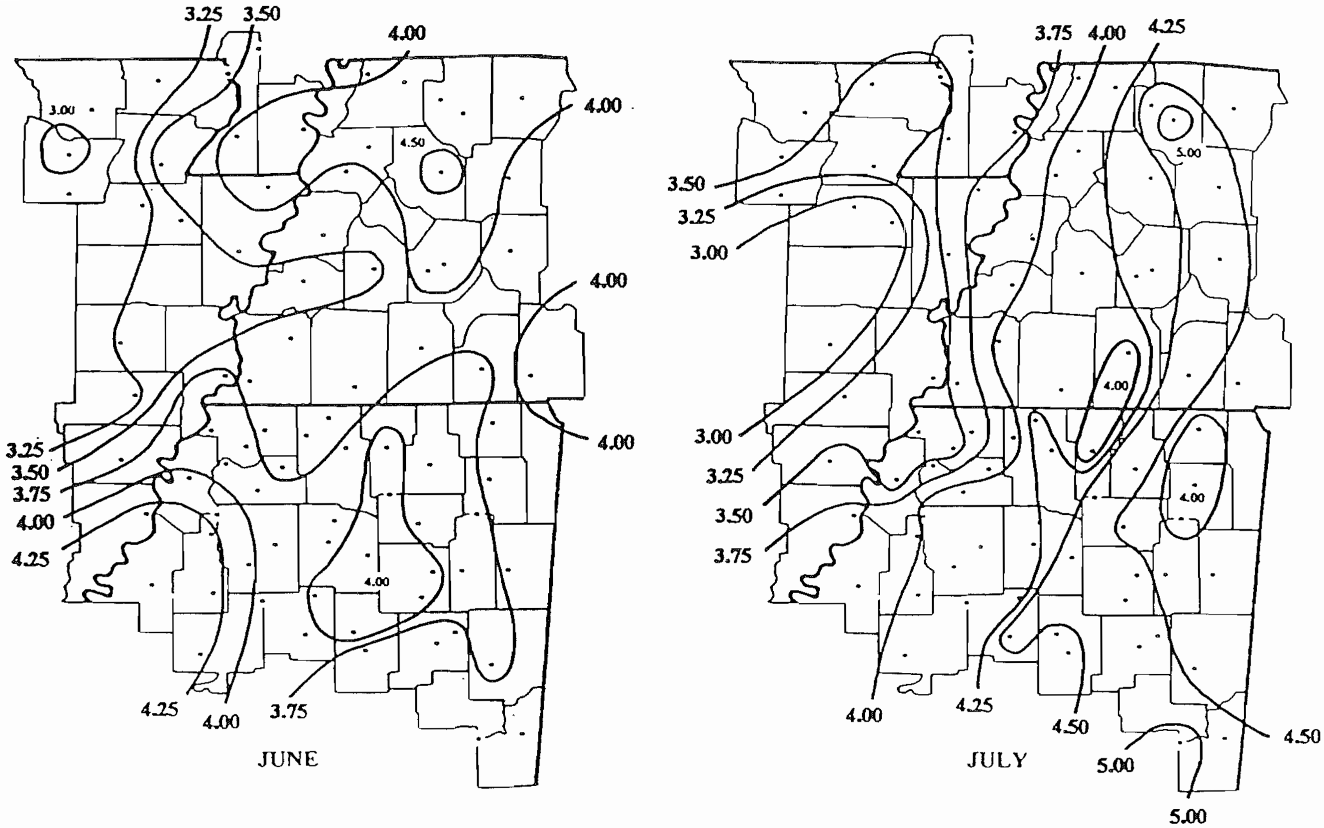


Figure 8. Distribution of 'normal' precipitation across Memphis CWA during spring.



(in inches)

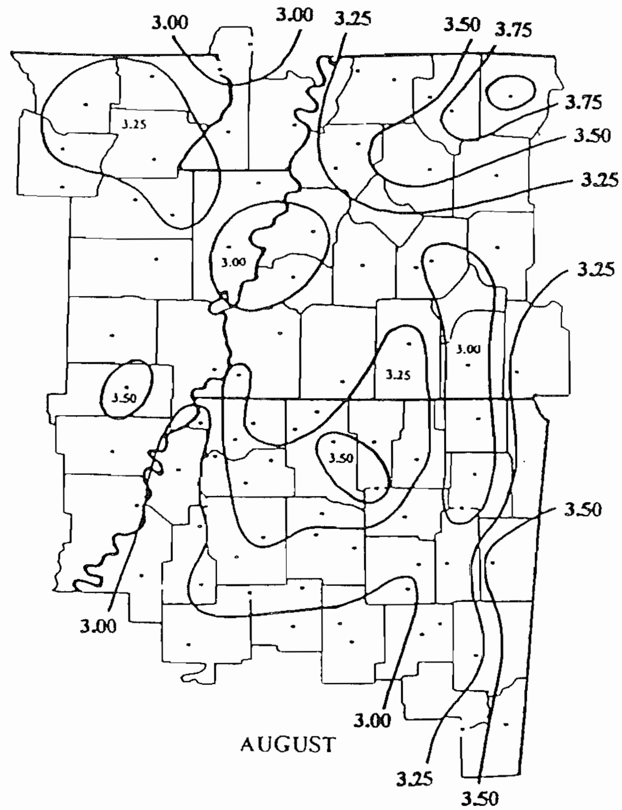
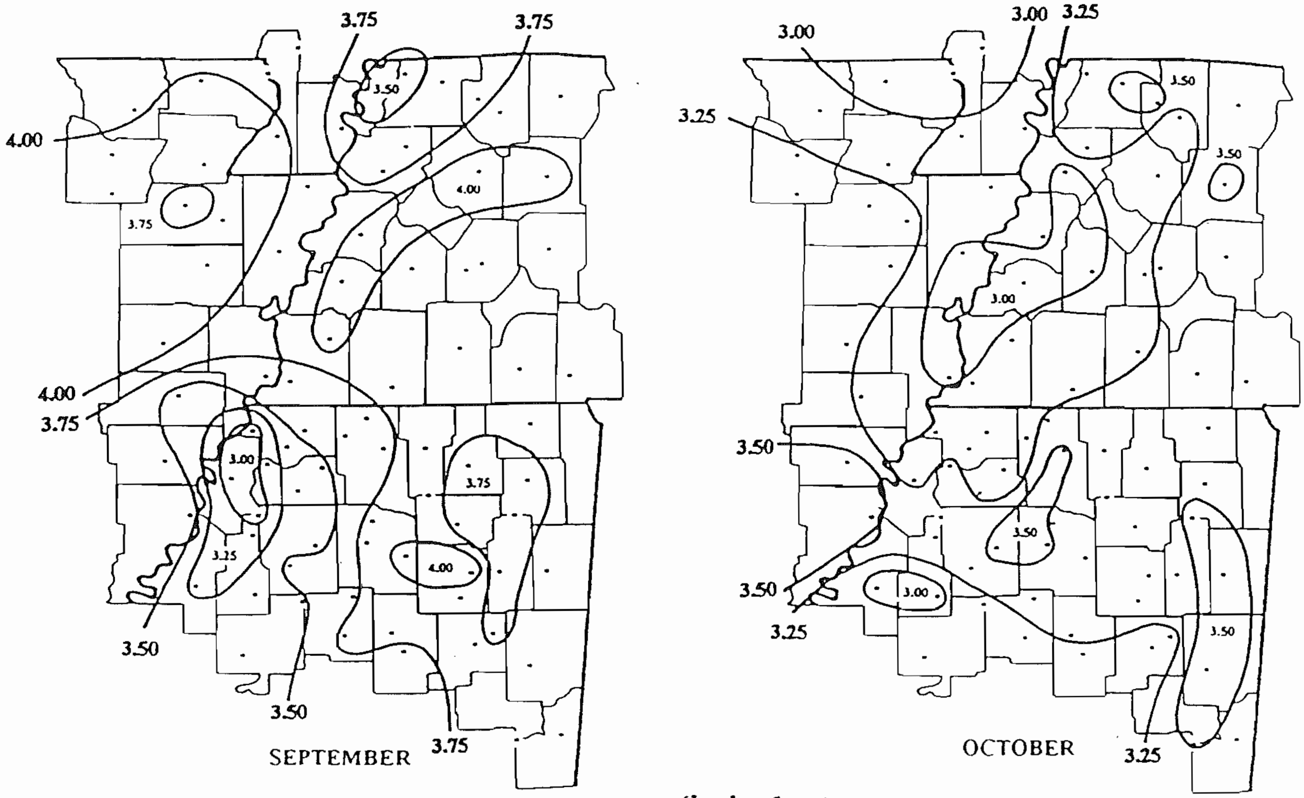
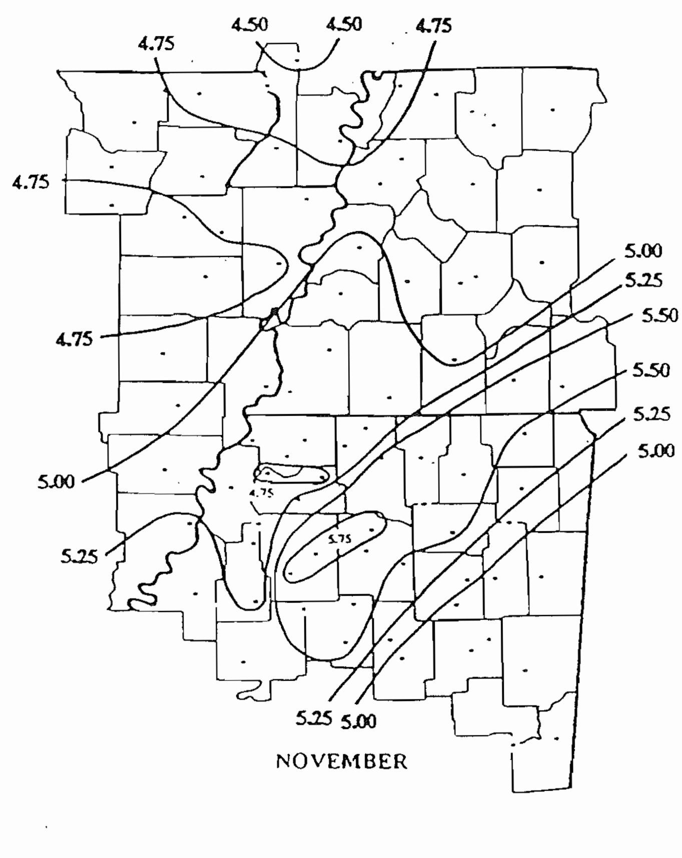


Figure 9. Distribution of 'normal' precipitation across Memphis CWA during summer.



(in inches)

Figure 10. Distribution of 'normal' precipitation across Memphis CWA during fall.



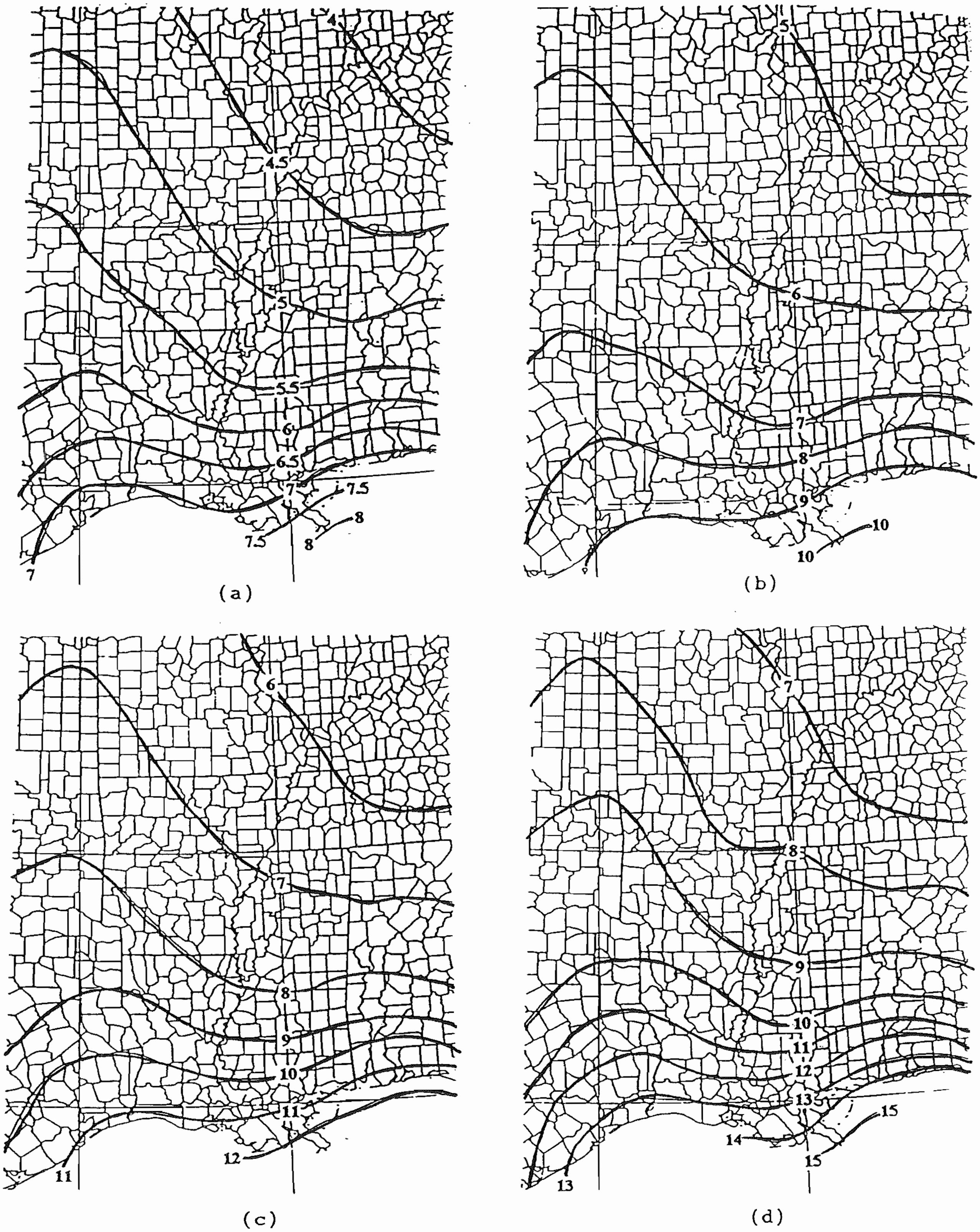


Figure 11. Maximum rainfall (in inches) expected once every 100 years in (a) 3 hours, (b) 6 hours, (c) 12 hours, (d) 24 hours. (From: 'Rainfall Atlas of the United States')

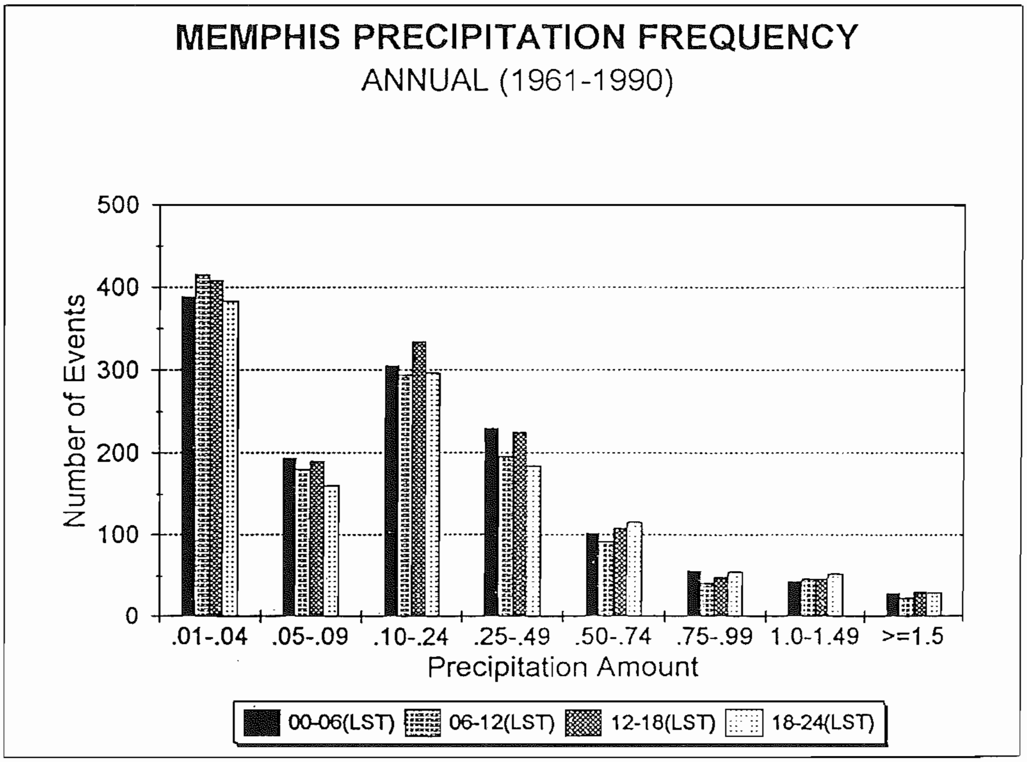


Figure 12. Memphis annual precipitation frequency.

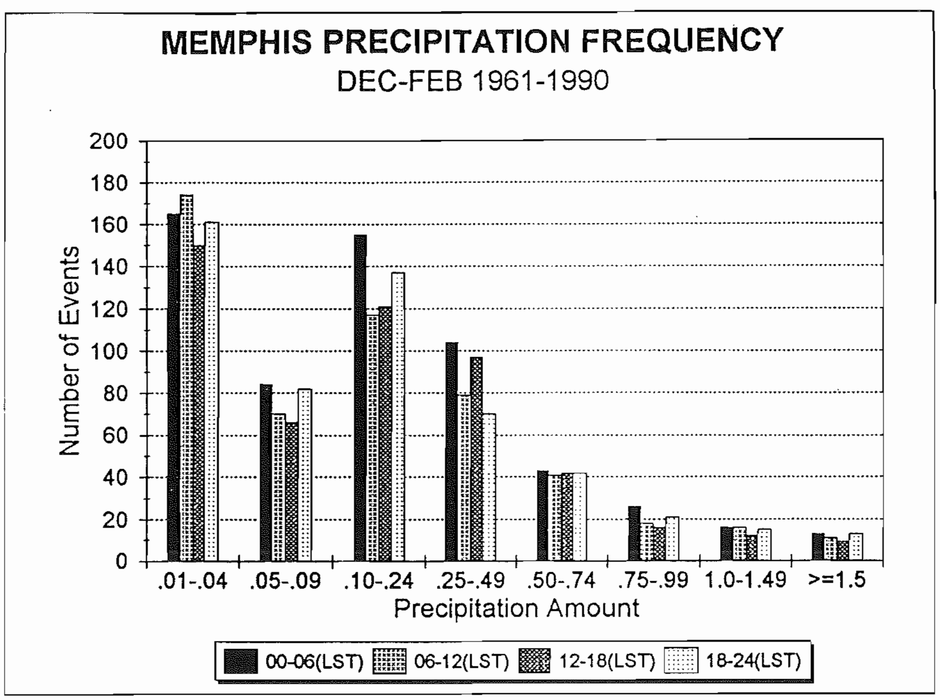


Figure 13. Memphis precipitation frequency during winter.

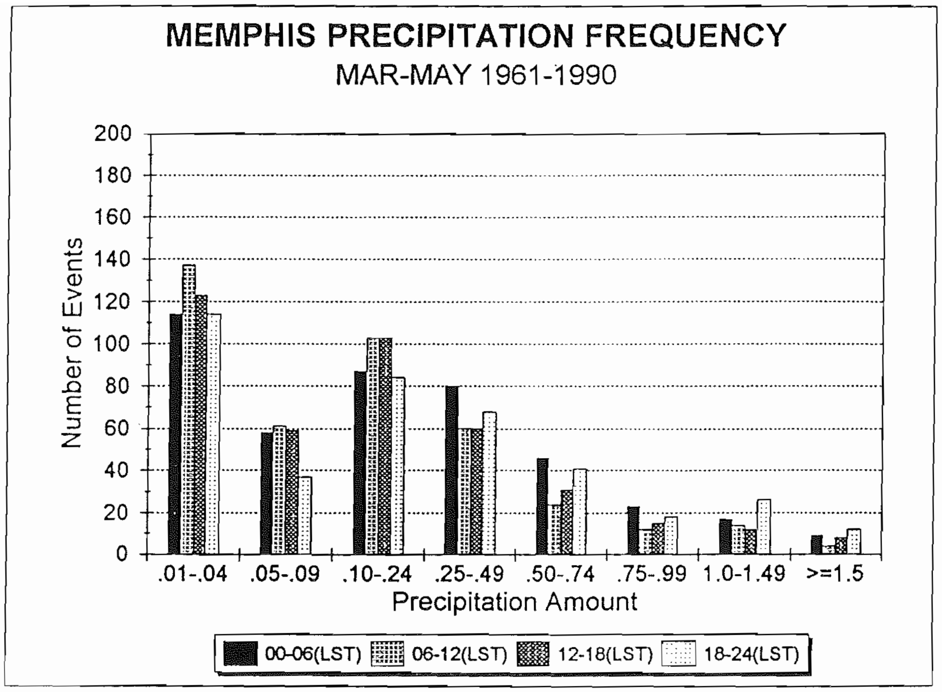


Figure 14. Memphis precipitation frequency during spring.

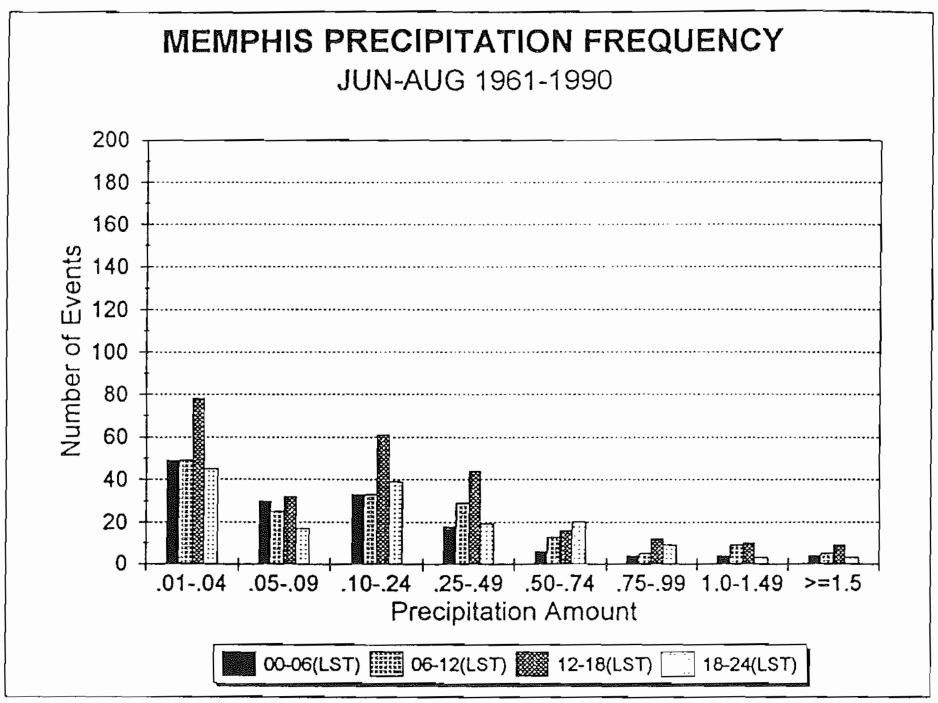


Figure 15. Memphis precipitation frequency during summer.

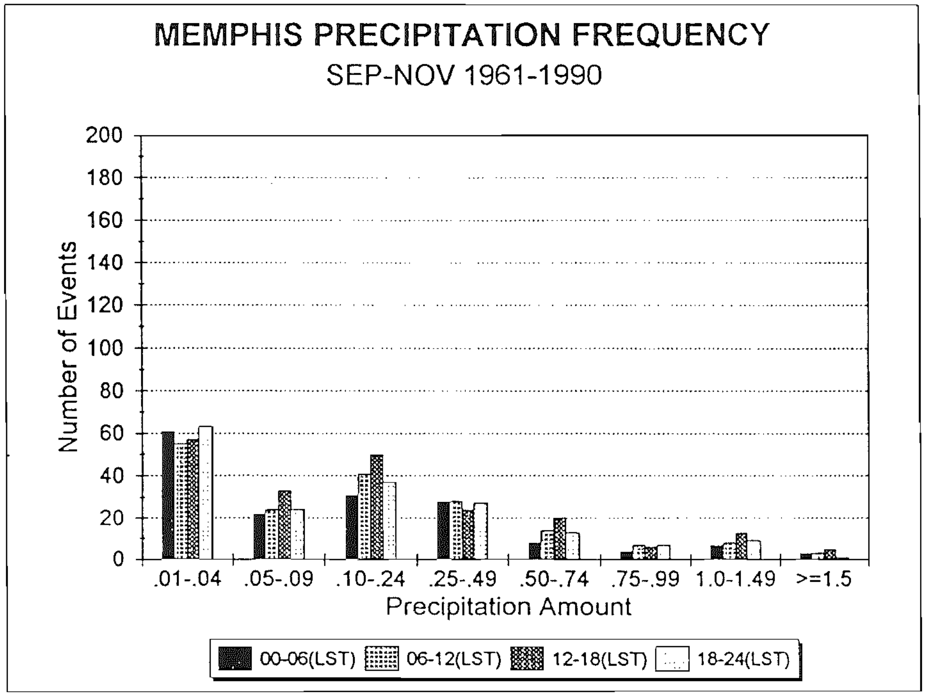


Figure 16. Memphis precipitation frequency during fall.

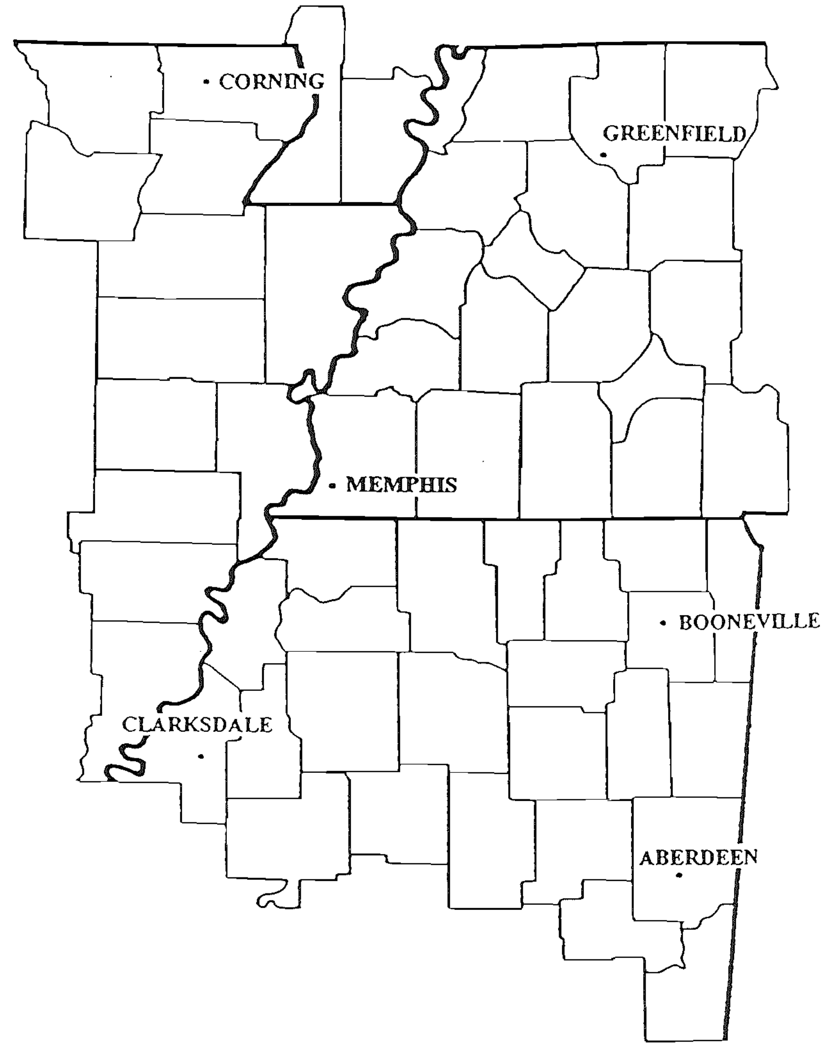


Figure 17. Stations reporting hourly precipitation data used to spatially represent Memphis CWA.